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COMPUTER-BASED EDUCATION AND TRAINING FUNCTIONS: A SUMMARY

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO, CALIFORNIA

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COMPUTER-BASED EDUCATION AND TRAINING FUNCTIONS:
A SUMMARY

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   This report provides brief descriptions of the functions a computer can perform in educational and training settings and a taxonomy of these functions to facilitate an understanding of their interrelationships in a computer-based instructional system. It is intended for those involved with operational educational and training facilities in both armed services and civilian organizations.

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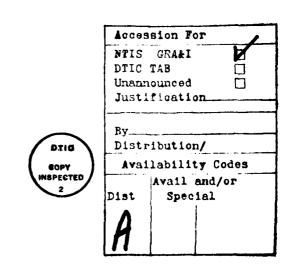1 JAN 73

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FOREWORD

This research was performed under advanced development subproject Z1176-PN.01 (Improving the Navy's Computer-managed Training System) and was sponsored by the Chief of Naval Operations (OP-01).

This report provides brief descriptions of the functions a computer can perform in educational and training settings and a taxonomy of these functions to facilitate an understanding of their interrelationships in a computer-based instructional system. It is intended for those involved with operational education and training facilities in the Navy, other services, and in civilian organizations.

The report was prepared while the author was a visiting scientist at the Navy Personnel Research and Development Center. He is an Associate Professor of Psychology at The Queen's University, Kingston, Ontario, Canada.

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SUMMARY

Problem

The initial use of the electronic computer in education and training during the 1960s was primarily as a sophisticated teaching machine to present programmed instruction materials and perform a limited number of management functions. During the 1970s, the range and diversity of education and training functions served by computers expanded substantially. Numerous general terms, such as computer-assisted instruction, computer-managed instruction, computer-based learning, and computer-integrated instruction, have been used to describe these functions. These terms have often been used in an imprecise and inconsistent fashion.

Due to the diversity of functions and the imprecision of terminology, it is difficult for individuals not directly involved in the field to develop an accurate perspective of the range of educational functions currently being provided by computers.

Objectives

The objectives of this effort were (1) to compile brief descriptions, suitable for individuals unfamiliar with instructional computers, of the education and training functions computers may serve, and (2) to organize these functions into a taxonomy to facilitate understanding of the interrelationships of computer functions in education and training.

Approach

Publications and technical reports concerning computer-based education and training were reviewed. Several training sites currently employing computers were visited and experts directly involved in computer applications were interviewed. This information was then integrated into the functional descriptions and taxonomy.

Results

1. __Instructional functions.__ Two major instructional uses were identified for the computer: (a) as a medium of instruction, in which the computer is used as a highly efficient means of presenting individualized tutoring, drill and practice, and textual/graphic information to students, and (b) as an instructional resource or tool that emphasizes such functions as simulation, modeling, educational games, and complex problem solving.

2. __Management functions.__ Partly due to increased emphasis on individualized instruction at all levels of education and training during the past 20 years, a number of administrative/managerial functions have assumed increased importance. These functions can be divided into the following major categories: (a) diagnosing abilities, attitudes and skills, and prescribing educational training sequences based on these diagnoses, (b) repeating individualized testing and feedback on course objectives, (c) managing each student's progress through the course, (d) arranging flexible scheduling of students, instructor activities, and all instructional resources, and (e) record keeping and reporting of the large amount of information associated with individual student and class performance throughout a course.

3. __Support functions.__ The computer may also be used to assist instructors, subject matter/courseware personnel, and administrators by providing a variety of support

functions. These include (a) authoring of instructional materials with associated word-processing capabilities for text production and editing, (b) research and evaluation of student and instructor performance as well as course materials, and (c) computer-based communications networks.

Conclusions

Increasing familiarity with the range of possible educational computer functions can help those directly responsible for training operations to optimize implementation of computer-based instruction.

CONTENTS

INTRODUCTION

Problem

Since the invention of the computer over 30 years ago, the types of tasks for which they are employed and the variety of situations in which they are used has continued to increase dramatically. Initially, computers were used for large-scale data calculations and analyses. This use of the computer, sometimes referred to as scientific computing, was centered primarily in university research settings and capitalized on the computer's capacity to perform extremely complex calculations in short time periods. A second, and continuing, major use of the computer has been for large-scale data handling by business, industry, and government. This function is referred to as data processing.

More recently, the computer has been used to accomplish a wide variety of tasks in providing formal schooling at institutions (education) and in teaching technical or vocational skills (training). Two general uses of the computer in these areas are to assist directly in (1) teaching or training a particular content area or skill (computer-aided instruction (CAI)) and (2) organizing and managing a course by performing such functions as test scoring, providing feedback of test results, record keeping, and scheduling (computer-managed instruction (CMI)).

Although CMI and CAI have quite distinct developmental histories, many current education/training programs have used various aspects of both to refer to the computerized components of courses by a bewildering array of terms, including CAI, CMI, computer-based learning (CBL), computer-based instruction (CBI), computer-assisted learning (CAL), computer-based education (CBE), and computer-integrated instruction (CII). The proliferation of such terms in describing various instructional programs that incorporate a wide variety of computer-based functions has rendered these terms essentially meaningless, except to indicate that a digital computer is involved in some capacity. Also, the state of the art in computer capabilities with actual or potential applications in education and training has expanded so rapidly that no simple set of terms, such as CAI or CMI, can accurately and exclusively communicate the diversity of functions currently possible.

Due to this diversity of function and the imprecision of terminology, it is difficult for individuals not closely involved in the field to develop an accurate perspective of the roles that the computer currently fulfills in education and training.

Objectives

The objectives of this effort were to: (1) compile brief descriptions of the various education and training functions computers may serve, and (2) organize these functions into a taxonomy to facilitate understanding of the interrelationships of computer functions in education and training.

This report provides readers who are part of the military training community with a single document that describes and relates, in simplified terms suitable for individuals unfamiliar with computers, the multitude of functions capable of residing in computer-based instructional systems.

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APPROACH

Current publications and technical reports describing education and training programs using computers in some capacity were reviewed. Additional information was gathered by visiting several computer-based training centers and interviewing a number of experts directly involved in computer applications. The programs reviewed covered a wide range, from small- to large-scale systems and from primary to post-secondary education, as well as industrial/military training.

Many computer-based functions were identified and a description of each function was prepared. Since the purpose of the effort was to provide a simple yet comprehensive list of functions, no systematic attempt was made to analyze critically their cost effectiveness and most appropriate areas of application or to develop a detailed bibliography. In some cases, however, editorial comments, examples, or references were included when needed for clearer understanding of the particular function.

Finally, the complete list of functions was arranged into a hierarchically structured taxonomy. This taxonomy was considered to be a convenient method of organizing and presenting the numerous functions that had been compiled and also of facilitating an understanding of the relationships of functional roles of computers in education and training. Various alternative approaches to forming the major categories in the hierarchy were considered (e.g., categorizing the functions according to whether they primarily affect students, instructors, or course administrators or according to the type of education or training environment in which they are typically applied). In the approach finally adopted, the functions were categorized on the highest level, according to whether they are associated primarily with instruction (1.0), management (2.0), or support activities (3.0). Subordinate functions are indicated numerically by an additional digit. Thus, a function classified as 1.1.1 is subsumed under the 1.1 function.

This hierarchical structure, which appeared to be the most conducive to placing the various functions into mutually exclusive categories while displaying functional relationships, was also compatible with other relevant reviews of computer use in education and training (Baker, 1978; Hooper, 1978; Lintz, Tote, Pflasterer, Nix, Klem, & Glick, 1979).

RESULTS

This section provides brief descriptions of various computer uses in education and training. The formal taxonomy listing these functions appears in the appendix.

Instructional Functions

Instructional computer functions are commonly referred to as computer-assisted instruction (CAI) in North America and computer-assisted learning (CAL) in the United Kingdom. CAI is defined as any teaching process that directly involves the computer in the storage and presentation of instructional materials in an interactive mode to provide and control an individualized learning environment. In a CAI system, the student typically works alone at a computer terminal in a room with multiple terminals. Since there is clearly a "control" component in CAI, CAI also involves the management of instruction to some degree. For simplicity, the management aspect of CAI is not usually referred to by an awkward acronym like CAI/CMI; nevertheless, student management is always intrinsic to CAI.

Hooper (1978) has pointed out that CAI is, in fact, the product of a synthesis of two quite distinctive "traditional" uses of computers in education, which he labeled tutorial CAI and laboratory CAI. These uses are described in the following sections.

Tutorial Computer-assisted Instruction

Tutorial CAI, which is a direct descendant of programmed instruction in teaching machines of the late 1950s and early 1960s, involves using the computer to provide, via an interactive terminal, sequences of instructional material and questions. Based on the student's answers to these questions, the instructional material can be adapted to each individual student via branching programs. This use of the computer was pioneered by members of the computer industry in the late 1950s to train their own personnel and was first applied to primary education by Dr. Patrick Suppes and his colleagues at Stanford University and to higher education by Dr. Don Bitzer with the programmed logic for automatic teaching operation (PLATO) project at the University of Illinois during the mid 1960s . Tutorial CAI has emphasized making education more efficient and cost effective via highly individualized computer-presented instruction.

Tutorial CAI takes on several different forms, depending on the capabilities of the particular computer hardware as well as the instructor/author of the course.

Information Presentation. The computer can be used to provide essentially a "page-turning" function in which text, graphics, or other audiovisual information are presented to the student via a display terminal and other computer-controlled apparatus, such as audio/videotape recorders, slide projectors, and videodisc players. Review questions are often presented via the computer terminal after a particular lesson or unit is completed and, based on the student's answers, the computer repeats various points or presents additional remedial materials.

Drill and Practice. This involved providing the student with repeated practice in using and applying the basic skills acquired through computer-based instruction or other media. Instant correction and guidance of these skills can be provided and the practice items can be presented at increasing difficulty levels. Also, the criteria for successful performance, in terms of such variables as speed and accuracy, can be automatically increased. Students may answer in various ways, such as teletyping alphanumeric or constructed responses or touching the display screen to answer multiple-choice questions. In addition to providing the student with ample practice and feedback, the computer frees the instructor from the tedious tasks of monitoring and correcting large numbers of practice problems.

Tutorial Function. In the tutorial form of CAI, the computer presents the student with very small units of information, questions on each segment of information, and immediate feedback concerning the accuracy of the answers. Typically, students are required to meet some criterion of understanding, as indicated by their answers to the various questions, before moving to the next segment of instruction. Extensive prompts and clues are provided by the computer and correct answers are immediately reinforced. In some tutorial programs, the student can ask relevant questions that the computer answers.

Since the goal of computer-based tutoring is to provide highly individualized instruction, branching, rather than linear programs are typically used. This feature allows students to receive different "branches" of instruction based on the accuracy of their answers and matches the material's level of difficulty to each student's current level of understanding. In this way, students of widely varying capabilities and entering knowledge

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can be "led through" quite complex information by the computer, which tailors the amount and difficulty of instruction for each student.

As with other computer-based instruction, a variety of forms of student-computer interactions is possible, including text, graphic, and audiovisual information presentation, and students may respond via teletypewriters or touch display panels. The computer is used extensively in the tutorial mode in scientific and technical education, where individualized, self-paced instruction of complex material is particularly desirable.

Laboratory Computer-assisted Instruction

Laboratory CAI involves instructional uses of the computer that take advantage of its capabilities to generate, simulate, and calculate information that otherwise would be impossible or impractical to present to students. Unlike tutorial CAI, which uses the computer primarily as a medium for presenting instructional materials, laboratory CAI uses the computer as a learning resource. As discussed by Hooper (1978), laboratory CAI has developed from its initial use of the computer solely as a research instrument to its current use as an educational tool for various disciplines such as physics, statistics, biology, and chemistry. Its development was pioneered at various universities, most notably at Dartmouth College where computing has been integrated into many undergraduate courses. Another distinctive characteristic of the research computing tradition from which laboratory CAI has developed is its use of scientific programming languages, such as FORTRAN, rather than authoring languages, such as TUTOR, commonly associated with tutorial CAI.

Hawkins (1978) recently surveyed individuals directly involved in computer-based higher education in the United Kingdom, Canada, United States, and the Netherlands. The respondents generally indicated great confidence and enthusiasm for the effectiveness of laboratory CAI in facilitating complex learning and problem solving, in addition to the more typical functions of test administration, drill and practice, and other tutorial CAI functions.

The following paragraphs will describe several examples of laboratory CAI as they occur in the specific areas of simulation, complex problem solving, and modeling and educational games.

Simulation. Recent advances in interactive computer graphics, as well as computer-controlled presentations of taped and filmed materials in the interactive mode, have spurred interest in the use of the computer to present students with a wide variety of simulated experiences. Two somewhat distinct educational applications of simulation have been identified: (1) the simulation of actual equipment and (2) the simulation and modeling of complex processes and systems.

1. Equipment simulation. The computer can simulate either simple or complex equipment. Computer-generated graphics or computer-controlled film, slides, videodisc, or videotape are used to present the student with a pictorial representation of the actual equipment on a terminal screen. The student responds to the visual representation either by touching the screen directly or via a keyboard. A data base, consisting of the operational characteristics of the equipment, is stored, and instructional programs are written to accomplish a variety of training goals. Thus, students can be taught the sequence of actions required to operate the equipment. Also, training can be provided in equipment maintenance, including problem diagnosis and necessary repair. If the students respond incorrectly, the computer can provide immediate feedback concerning the correct

response, require that mistakes be corrected, and provide information about the effects of a particular mistake.

This type of computer simulation is particularly well suited to technical training, since students can be offered extensive and highly individualized learning experiences with complicated equipment that would be too dangerous or costly to provide using the actual equipment itself. The Navy Personnel Research and Development Center (NAV-PERSRANDCEN), San Diego, is developing an electronics equipment maintenance trainer for application in Navy technical training schools (Pine, Daniels, & Malec, 1981; Pine, Koch, & Malec, 1981; Wylie & Bailey, 1978).

2. <u>Simulation of complex systems and processes</u>. Computer simulations can also be used to teach students about complex operating systems and processes. Students are given the opportunity to manipulate various parameters to observe the effects on the total system or a particular aspect of the system. This computer-based function has been of particular interest to higher education because it can provide students with a "dry lab" facility in which experiments can be run and outcomes observed quickly and efficiently. For example, students can explore hereditary processes by simulating a large number of breeding experiments to observe the effects of various genetic combinations or they can observe how variable population factors influence population growth in various countries by inputting these factors. This function also has potential applications in technical training for simulating complex electrical and/or mechanical systems to allow students to explore the interrelationships among various system components. For example, work is currently underway by the Navy on a computer simulation of a high pressure steam propulsion system in operation to allow students to learn how each component in this highly complex system functions (Stevens, Roberts, Stead, Forbus, Steinberg, & Smith, 1982).

<u>Complex Problem Solving and Modeling</u>. Because it can store large quantities of information and perform complex calculations extremely quickly, the computer can solve problems that would otherwise be impossible to solve. Consequently, it can be used to teach certain concepts by allowing students to solve problems numerically where previously such concepts could only be taught analytically.

Also, the computer can be used as a theoretical laboratory where models can be developed and tested by comparing computer-generated data for a particular model with empirically derived data. The use of the computer has been most prevalent in the areas of physics, theoretical mathematics, and artificial intelligence and represents a merging computer use for educational and research purposes.

<u>Educational Games</u>. Educational games present problems and questions using entertaining animation and graphics. They induce a sense of challenge and interest by providing performance in terms of winning or losing, number of points accumulated, or by pitting one player against another in competition.

Due to the recent technological advances in microprocessors and interactive graphics, a variety of educational games have appeared in hand-held form and as options on microcomputer systems. To date, these electronic games have consisted primarily of interesting drill and practice exercises in basic mathematics and language skills. Since some computer-based games are being used in higher education, it is likely that this computer capability will be employed more frequently as teachers and instructional developers become more familiar with it.

Management Functions

The use of the computer to aid the instructor in carrying out various management functions is usually referred to as computer-managed instruction (CMI). Baker (1978) has defined CMI as "a total educational experience in which a computer-based management information system is used to support the management functions performed by the teacher" (p. 14). CMI systems do not provide instruction but are coordinated with a physically separate instruction curriculum. Students may take CMI tests, but they actually receive instruction from texts, workbook, or other media formats away from the computer. The management functions themselves have taken on increasing importance in the field of education and training due to the recent emphasis on individualized instruction, mastery learning, and repeated criterion-referenced testing and efforts to develop and evaluate instruction systematically.

Baker points out that, by the mid 1960s, it had become increasingly clear that more efficient methods were required to process the large amount of information fundamental to the implementation and evaluation of individualized instruction. At that time, educators began to assimilate computer-based data processing procedures that had been successfully developed in support of a number of management functions in the industrial and commercial sectors. Since that time, the use of computers in a management capacity by educators has continued to expand, and it currently encompasses a wide variety of functions that are described in the following sections. The descriptions presented herein were compiled with the aid of several recent discussions of CMI by Baker (1978), McCombs and Dobrovolny (1980), and especially Lintz et al. (1979).

Diagnosis

Genuinely individualized instruction requires that individual differences in student aptitudes, attitudes, skills, and previous training be considered in making decisions about remediation, course assignments, etc. The computer can be used to collect, store, and organize this information in support of further decision making. This diagnosis of individual student characteristics can be done on a "one-shot" basis prior to course enrollment or on an ongoing basis throughout the course.

Precourse Diagnosis. Before beginning a particular course or program, a student can be administered a variety of tests and questionnaires to obtain information for making various individualization decisions. This assessment can cover a wide range of potentially relevant variables such as: (1) entry skills directly related to course objectives, (2) general or course-specific abilities, (3) general or course-specific motivation, personality characteristics, and interests, (4) learning styles and strategies, (5) specific study habits and skills, and (6) general background and biographical variables.

Within-course Diagnosis. In addition to assisting in precourse assessment, the computer can collect and organize diagnostic information while students are actively involved in the course or program. With this function, updating and modification of the initial individualization decision can be based on such within-course measures as (1) changing student interests and motivation, (2) changing learning styles and preferences for alternative course presentation modes, and (3) various course performance variables such as time or number of quiz attempts required for mastery and overall progress rates.

Prescription

The prescription function refers to the decision-making process whereby individual students are assigned to a wide variety of course activities including different remediation tasks, course alternatives, and counseling. Ideally, these prescriptions are based, at least in part, on computer-generated predictions statistically derived from the diagnostic measures collected before and during the course.

Precourse Remediation.   Before students who have been identified as having deficiencies in certain skills are allowed to begin a particular course or program, they are assigned to specific remediation activities.   The computer can prescribe the most appropriate activities to individual students based on their particular deficiencies.   For example, students can be assigned to special materials or exercises designed to improve specific reading or mathematical skills, or more general study habits and skills such as attention, memorization, and test-taking skills.   This function is frequently used in operating training systems.

Within-course Prescription.   In many individualized courses, the particular assignments vary from student to student. The computer can make these assignments, based on precourse and within-course measures of student characteristics and performance or on different course objectives for certain types of students.

1.   Assignment to alternative course versions.   Students may be assigned to course versions that differ in content for experimental purposes or because the material in one version is considered to be more relevant to the goals of certain students.   For example, students who will be going on to advanced training in electronics may be assigned to a different version of a basic electronics course than students who will receive no further electronics training.

2.   Assignment to alternative lesson formats.   By considering the diagnostic information, the computer can make individualized assignments within a particular version of a course such as printed versus audiovisual presentation of course materials. As a matter of economic practicality, though, multiple-media versions for the same content are rarely available and, even less frequently, are students assigned on the basis of aptitudes.

3.   Assignment to alternative remediation activities.   Based on course performance, the computer can assign each student to a particular type of remediation activity, such as restudying certain points, studying additional materials, or having individual discussions with the instructor.   In making these assignments, the computer can consider such information as the success of various remediation alternatives on previous occasions and resource availability.

4.   Student self-prescription.   In most CMI courses, either the instructor determines the individual student assignments by taking the computer-provided information into consideration or the computer provides an assignment to each student directly.   In some instances, however, it is better to permit students to select the course version, lesson sequence, or type of material.   This capability is better in general-knowledge courses in which minimum course objectives can be augmented with extra material for interested students.   The computer can easily support this function by providing each student with the array of available options.

Discussion.   The complementary functions of diagnosis and prescription provide extensive opportunities for individualizing instruction.   With the use of the computer, the

potential variety of options is virtually unlimited; however, Baker (1978) has noted that, in practice, CMI courses have failed to take advantage of this tremendous individualization potential. In most CMI systems, diagnosis consists simply of listing the course objectives that each student has failed to master. Although many computer-based instructional systems include the capability for sophisticated diagnosis at both the pre- and within-course levels, the actual diagnosis methods employed are severely restricted, possibly, Baker surmises, by the lack of knowledge concerning relevant predictor variables.

Likewise, most current implementations of the prescriptive function, although performed automatically by the computer, consist primarily of one-to-one relations between missed objectives and specific remediation activities. Often these prescriptions consist of restudying the same content, using the same instructional approach but a different media presentation if available.

Thus, it appears that, although the computer has provided the field of education and training with the capability of performing complex diagnosis and prescriptions for each student, the actual applications to date have failed to take full advantage of this capability. Baker noted that this indicates the lack of real theoretical bases in education and training for both diagnosis and prescription; however, it may also be due to the very high costs associated with developing multiple-media instructional materials.

Student Testing and Feedback

In recent years, testing and feedback have assumed increasing importance in many areas of education and training. Rather than relying solely on a small number of major review tests, many instructors now provide a large number of tests on smaller units of instruction. Also, mastery learning, which requires each student to pass all tests at a minimum level of performance, and self-pacing, which allows each student to take a test when prepared, necessitate the administration and scoring of an extremely large number of tests in any course adopting these options. The computer can be used in a multitude of ways to select, administer, and score student tests and to provide both students and instructors with highly detailed feedback concerning test results.

Individualized Test Selection. The computer can be used to select the particular form of a test that a student is to receive and to determine whether the test is to be taken on-line (from a terminal) or off-line (independent of the computer).

1. Test form selection. In making the assignment, the computer can assign a particular test form randomly or consider such information as individual student characteristics and the test forms the student has already received. The most complex type of test form selection involves having the computer construct unique test forms for each student by randomly selecting test questions from a computer-stored test-item bank.

2. On-line versus off-line assignment. The computer can assign students to on- or off-line testing, if both capabilities exist. This assignment can be made based on such considerations as terminal availability or particular student requirements for on-line testing.

Scoring of Tests Taken Off-line. The computer can score multiple-choice or true-false tests taken off-line, most typically via an optical scanning device, and can be programmed to score these tests in a variety of ways. Lintz et al. (1979) have recently identified the following set of possible off-line scoring options:

1. <u>Preset criterion</u>. Each answer is scored as right or wrong with a designated percent correct required to pass.

2. <u>Correction for guessing</u>. The total score on a test is automatically corrected by a pretest factor for guessing.

3. <u>Question weighting</u>. Some test questions can be weighted more than others.

4. <u>Scoring based on objectives</u>. In criterion-referenced testing, one or more test items are associated with each instructional objective. To pass a test, the scoring criteria may require that a certain group of objectives be passed or that a specific test question be answered correctly to pass a particular objective.

5. <u>Scoring based on performance tests</u>. Although direct performance-based test scoring is not possible off-line, the computer can score and provide feedback on performance checklists completed manually by the student or instructor.

<u>Test Feedback to Students</u>. Many instructional systems attempt to provide students with immediate feedback concerning test results. This is virtually impossible to accomplish without the aid of a computer for a large number of students, each of whom may be taking a different test. This computer-based feedback may be in various forms:

1. <u>Test scores</u>. Test scores can be provided in terms of number and/or percent correct and can be corrected for guessing.

2. <u>Item analysis</u>. The feedback to the student can be a list of test items not answered correctly. Detailed analysis data would be collected from a number of students and would be used by course developers to improve instructional material or tests.

3. <u>Next assignment</u>. The computer can also provide the students with their next assignment, which might be to another version of the test, a remedial study activity, or the next study assignment.

<u>On-line Testing Capabilities</u>. Compared to off-line testing, on-line is more expensive and consequently has not been employed as extensively. However, a number of potentially valuable on-line testing capabilities exist and, with declining costs of micro- and minicomputers, adopting interactive testing may become substantially more feasible in the future:

1. <u>Constructed response answers</u>. Short-answer or fill-in-the-blank questions, which require the student to construct or recall an answer rather than merely to recognize the correct answer as in multiple-choice or true-false questions, can be used. Here, the student enters the answer on a keyboard and the computer evaluates the adequacy of this answer and provides immediate feedback. This type of item ensures proper assessment of mastery of learning objectives that require cognitive recall.

2. <u>Varied presentation orders</u>. When the computer generates random presentation sequences or orders for test question and alternative answers, the instructor or test developer does not have to construct alternative test forms. The test items are stored in an item bank. The random generation of questions and varied presentation orders aid in ensuring test security and thereby decrease the opportunities for cheating.

3. <u>Individualized test construction</u>. Students receive different tests or test items, depending on their performance on previous sections of the course or on previous

questions on that particular test. Also, subsequent retesting can be programmed to include those items or objectives not satisfied on previous tests.

The computer has been used extensively to provide highly individualized testing and feedback both on- and off-line. The respondents to a survey of educators involved in computer-based education (Hawkins, 1978) viewed this testing function as very important and likely to continue as a major role of the computer in assisting education and training.

Student Progress Management

Although student progress is an important concern to instructors in any situation, this seems to be particularly true in self-paced courses. Since students in self-paced courses are given some degree of freedom in determining their rate of progress through the course, they frequently procrastinate. Another area in which student progress is of special concern is in individualized courses that allow students to enter one at a time rather than as a class and that can accommodate only a fixed number of students. In such courses, it is very important to predict when students will finish so that others can take their place with a minimum of waiting. Also, in these self-paced, variable-entry courses, which are characteristic of many of the technical training courses operated by the military, the speed at which students progress through a course has an immediate economic consequence because the students are paid during training. If training time can be reduced, there will be a direct reduction in training costs.

Progress Forecasting. Completion times may be estimated for each student registered in the course. These predictions, which are typically based on a number of variables (e.g., aptitude test scores, age, and years of education), are combined statistically by the computer to yield an estimated completion time.

1. Lesson completion estimates. The computer can predict how long each student is expected to take on each lesson within the course. These predictions can then be used to schedule the use of various instructional resources and testing sites.

2. Course completion estimates. A course completion time can also be predicted for each student. This information can be used to plan for incoming students and to schedule subsequent courses or job assignments for graduating students.

3. Initial versus revised predictions. Predicted unit and course completion times can be generated based on various measures of student characteristics and abilities that are available at the time a student registers. These measures might include aptitude test scores (such as the Armed Services Vocational Aptitude Battery Subtests), age, previous schooling, and performance in other courses. After the student begins the course, however, various measures of performance in that course, such as the amount of time taken to complete each module, can be integrated into the prediction equation to produce revised (and hopefully more accurate) predicted completion times for subsequent units and the course as a whole.

4. Identification of problem students. Based on the progress forecasts, it is possible to identify students who are spending substantially more time than expected on various lessons. Early detection by the computer of students who are experiencing some problems with the course, as measured by their progress, can be used by the instructor in deciding which students may require special guidance or counseling.

Feedback and Motivation. A variety of procedures have been used to encourage students to maintain adequate progress. Many of them require direct use of the

computer. They range from providing students with individual progress reports to presenting various positive and negative incentives.

1. Individual progress reports. The computer can provide students with periodic status reports, either on a daily basis or as part of the feedback following the scoring of each test. Although the form of these reports can vary substantially from course to course, typically the student's current status is compared either to his predicted status or to the average progress of the class. This information is usually printed out by the computer in alphanumeric form, but can be presented as a chart that graphically portrays the student's on-going progress either in absolute terms or relative to some standard.

2. Incentives. Many courses employ various rewards and punishments in an attempt to motivate the students. These incentives include rewards, such as brief praise statements, official letters of commendation, points for desirable performance that can be exchanged for prizes or desirable activities, or time excused from classroom activities. On the negative side, there are letters of censure, assignment of additional study time, or loss of points for undesirable performance or slow progress in the course. The computer can be programmed to identify positive and negative academic performance by individual students. The instructor can then decide on the particular reward or punishment or the computer can perform this function by scheduling and presenting the various incentives according to prespecified performance criteria for the class.

Flexible Scheduling

In individualized and self-paced courses, the scheduling function assumes enormous importance. A large number of student and instructor activities, as well as instructional resources, must be organized for the course to operate with maximum efficiency. The computer is well suited for scheduling students, instructors, and resources in an optimum manner.

Scheduling Student Entries. By matching individuals awaiting course registration with information concerning current course enrollments and predicted graduation times, the computer can notify students and their superiors when they should be available to start the course. This function is particularly important in many military training courses in which students can begin a course at any time, depending on the availability of space.

Scheduling Instructor-student Interactions. The computer can schedule meetings between the instructor and individual or groups of students for a variety of purposes.

1. Individual instruction. In some courses, specific topics or skills are taught on a one-to-one basis. This may involve a demonstration of particular equipment or discussion of a particularly difficult point by the instructor. To minimize wasted time, the computer can schedule these meetings by considering the daily activities of both the instructor and the student.

2. Small group instruction. The computer can identify homogeneous groups of students, based on their capabilities and progress through the course, to schedule meetings of these groups with the instructor for special lectures, demonstrations, or discussions.

3. Guidance and counseling. When problem students are identified, either by precourse testing or poor course performance, the computer can schedule the student for guidance or counseling meetings with the instructor.

4. _Performance evaluation._ Technical training courses often include evaluating student skills such as operating, troubleshooting, or repairing a particular piece of equipment. Typically, this evaluation requires individual evaluation by an instructor or course assistant. The computer can schedule these sessions, based on student performance and instructor/equipment availability.

Scheduling of Instructional Resources. Most current individualized courses employ many different types of instructional resources, media, and materials, such as video/audio tapes, slides, microfiche, interactive computer terminals for instruction and/or testing, individual or small group lecture/discussion facilities, laboratory equipment, instructional manuals, simulators and trainers, and various supplies. The computer can either assign students directly to these resources or present certain options to each student. In scheduling these assignments, the computer can consider a number of variables, such as individual student characteristics, preferences, and course progress, as well as resource availability. The computer can also monitor the use of each resource and notify the instructor or course manager when supplies of certain materials are low, or when particular pieces of equipment require service or replacement.

Out-processing Activities. As a student approaches the end of a self-paced course, the computer can schedule a variety of post-course activities, such as arranging the time and place for a final examination, scheduling registration in subsequent courses, and arranging for transfer of student records to subsequent schools, job sites, or military assignments. The computer can even generate diplomas, travel orders, and other necessary documents.

Record Keeping and Reporting

Collecting, storing, processing, and reporting the vast amounts of data generated by individualized, self-paced courses were among the earliest and most extensive uses of the computer in managing instruction.

Data on student capabilities, previous training/education, and progress through the course; information concerning course instruction and testing materials; and measures of instructor and student performance in the different courses within a particular school or training center can be collected and processed, with reports prepared regularly. The sophisticated large-scale data processing capabilities of present day computers, first developed for business and industry, are ideally suited to these tasks. Although many different types of computer-based records and reports are used in CMI courses, they can be conveniently categorized according to whether the information is intended primarily for course instructors or course/school administrators. A third type of report, used primarily by individuals involved in the development, implementation, and evaluation of instructional materials, has been classified here as a support function and is discussed on p. 17.

Reports for Instructors. To operate an individualized course adequately, the instructor must have easy access to information about each student and the class as a whole. This information can be generated regularly on reports produced by the computer with the instructor able to request a particular report as needed. These reports are important aids for the instructor in managing and counseling students.

1. _Class reports._ The computer can print periodic (e.g., daily or weekly) reports about each student in the classroom or learning center. These reports, which are designed to keep the instructor constantly apprised of the students currently registered in the course, might include such information as names, ages, military rank and specialization,

attendance records, and current lesson or unit of instruction. Additional information can be highlighted so that the instructor can easily identify any students in need of special attention. Such "flags" might include students who are falling substantially behind the class or their predicted progress rate in a particular lesson or the course as a whole, or students who have failed a specified number of quizzes on a given lesson.

2. Individual student reports. Extensive information on individual students can be conveniently compiled and reported by the computer, eliminating the need for more time consuming and expensive paper files in many cases.

a. Individual progress reports. When a student requiring special attention is identified, the instructor might want more extensive performance data than is provided on the classroom report. The computer can provide such individual student performance data as: (1) number of lessons completed, (2) number and scores of quizzes in each study unit, (3) the amount of time the student is ahead or behind the class average or his predicted unit or course rate, (4) the amount of time spent on various remediation activities, and (5) the amount of positive and negative incentive credits earned by the student and type of reward or punishment applied.

b. Student history reports. The computer can also be used to compile individual student history reports. These reports, which can be used by the instructor for guidance and counseling, can follow the student to subsequent courses or job assignments in hard-copy form. Information can include (1) biographical data such as birth date, birth place, education, and vocational history, (2) precourse attitude, skills, achievement and aptitude measures, and (3) any additional measures collected during or at the completion of the course. Examples of these additional measures are final course grade and ranking, certification earned, and instructor's comments concerning overall student performance and attitude characteristics.

Reports for Administrators. Course managers, supervisors, or principals use computer-generated administrative reports for a variety of purposes, such as instructor evaluation, cost-effectiveness studies, and structuring organizational hierarchies. These administrative reports, which can be generated by the computer on a regular basis or called up when required, might include: (1) the number and qualifications of students awaiting training, (2) the number of students currently enrolled in the various courses in the school/center, (3) the distribution of completion times for individual lessons and courses, (4) use of various instructional resources, and (5) instructor performance as indexed by the number of students and amount of time in various instructional activities.

Discussion. The computer can perform a wide variety of management functions, which have just been described. Indeed, the computer has made—and may well continue to make—its most important contribution to education and training in this area. In his recent review of computer contributions to education, Baker (1978) states that, when used in support of educational management, the computer is doing what it does best--collecting, processing, storing and reporting large amounts of data. Hence, CMI has been demonstrated to be a cost-efficient use of the computer in a variety of education and training locations. On the other hand, Baker also states that, when used directly in an instructional mode, the computer is doing what it does least well; namely, to communicate with many on an individual basis. The fact that very few CAI applications have been found to be cost effective appears to support Baker's argument. However, some have argued recently that, with reduced hardware costs and improved support for the production of courseware, the use of the computer in a primary instructional role holds substantial promise for the 1980s (see the special issue on "Trends in Computer-assisted Instruction" in the April 1978 volume of Educational Technology). With the present state

of affairs, additional data on the cost and effectiveness of various applications of CAI and CMI are likely to shed more light than are additional arguments about these matters.

Support Functions

The computer provides a number of functions that are not instructional or managerial in nature but, nonetheless, make important contributions to education and training. These functions include authoring, word processing, research and evaluation, and computer-based communications networks.

Authoring

When the computer is used in the interactive mode (i.e., CAI) to provide instruction directly to students, the instructional information must be written and stored in the computer. This process, which is referred to as authoring, involves translating all the instructional material (test questions, text, graphics, and decision rules) into a form or "code" that the computer can understand. Dean (1978) defined authoring as "a tool used by an educator to translate intents and purposes from his head into a computer program" (p. 20).

There are a variety of approaches to authoring, and the refinement and improvement of authoring systems is a major concern to any computer-based instructional system due to the extremely high costs traditionally associated with the production of CAI course-ware.

Originally, CAI programs were written in a general purpose language (such as BASIC), but since this required extensive experience with a language not particularly suited to the preparation of course materials, a number of special authoring languages were developed. Although these languages (such as TUTOR), substantially simplify authoring, a number of quite independent skills are still required; Montgomery and Judd (1979) recently characterized these authoring systems as requiring an individual who is a "versatile professor, an expert in the subject matter, an experienced teacher with sound but innovative ideas about instructional presentation, and a capable programmer" (p. 20). Since such individuals are hard to find outside of university computer science or physics departments, a team approach, involving a course author, a subject-matter expert, an instructional design expert, and a computer programmer, has often been adopted in other environments. Although this approach has worked reasonably well in some locations, difficulties with coordinating the functions of team members and high costs are commonplace.

Other approaches to authoring have attempted to eliminate the use of authoring languages entirely and to allow the author to communicate with the computer in English. This is done by programming the computer to carry out what is essentially an editorial function. The author specifies the contents of instruction, often in response to certain questions asked by the computer via an interactive terminal. This content is treated by the computer as data and, using a lesson-generating program, the computer converts it to instructional materials.

These computer-based editing systems can be used by instructors who know virtually nothing about computers or programming languages to author various course material for on- or off-line use.

On-line Tests. The computer can assist the course author in the production of test questions to be used in on-line CAI. The author can produce test questions either on-line, by giving the computer particular instructions via a display screen, or off-line, by using

lesson planning forms for entry by a coder. This computer-editor might simply instruct the author to type in the particular test question and the various alternatives (for multiple-choice questions) or an acceptable answer (for constructed response questions). Additional features would be to request the instructor to indicate the type of feedback to be provided to the student following a correct or incorrect answer, to format the test questions automatically, to offer the author the option of randomizing the presentation order of questions and alternative answers, and to control the number of attempts a student is allowed to make on each item.

On-line Instructional Materials. The computer can also be programmed for an editorial function in the production of on-line instructional materials. The advantage of this computer-based editorial function is that the author is not required to learn a programming language or construct lessonware with a programmer. The authoring editor can be programmed to provide the author with a variety of services and options. In developing tutorial or drill-and-practice CAI materials, for example, the editor can provide automatic formatting and structuring of the sequence of text frames and questions. The editor can copy text frames, questions, and graphics from other CAI lessons and suggest good instructional practices to the author.

The editor can be programmed to allow the author little or no freedom in determining the overall structure of the instructional program. This is exemplified by the time-shared interactive computer controlled instructional television (TICCIT) authoring system, in which the editor incorporates a specific instructional strategy and the author essentially molds the course content to fit this imposed strategy. Alternatively, the computer editor can be written to provide the author with various choices regarding the overall instructional strategy, although programming assistance in implementing various options may be required.

Off-line Instructional Materials. While the primary use of computer editors will probably be for CAI materials, this editorial function may also be used to develop and revise instructional and test materials for off-line use. Thus, for example, an instructor might use a test editor to write a multiple-choice final test. A hard copy of the final version could be reproduced for paper-and-pencil presentation. At another time, the instructor could revise the test, changing, adding, or deleting certain questions from the first version.

Word Processing

The computer can also be used to process, analyze, and evaluate textual information for a variety of noninstructional uses. This general category of computer use, which is labeled word processing, is divided into two main subcategories, text editing and text analysis. It should be noted, however, that the use of a CAI computer for word processing activities is, at best, ill advised. The capabilities may exist but the word processing, if extensive, may interfere with CAI operation.

Text Editing. The text editing function is similar to that provided for the development of text/graphic instructional materials except that the author can develop the text in any form desired without any structural constraints imposed by the computer. Computer-based text editing allows the author to enter an initial draft of a report or manuscript into the computer via an alphanumeric keyboard and, while still in soft copy form, to correct spelling and grammatical errors by replacing letters or word quickly and easily.

More extensive revisions, such as deleting, inserting, or changing the sequence of sentences or paragraphs, can also be easily accomplished. The draft can be stored for later work and the author can easily jump to any location in the manuscript to review or revise a particular section. When the manuscript is in final form, a hard copy can be produced on a printer.

Text Analysis. Text analysis involves the identification of particular qualitative characteristics of textual information. The computer analyzes large amounts of text quickly and accurately to identify a variety of characteristics.

1. Misspelled words. By entering a dictionary into the computer memory, the computer can identify any misspelled words in the instructional materials.

2. Readability estimates. In developing instructional materials, a major concern to the author should be whether the students will be able to comprehend the information adequately (i.e., whether the level of intelligibility is appropriate for the students who will be using it). One way of dealing with this issue is to determine the readability of the instructional materials. Although a variety of procedures and formulas have been used to estimate the readability of textual material, most involve analyzing the material in terms of word difficulty, syntactic complexity, or both.

a. Word difficulty. The difficulty of the words used in any textual passage can be calculated by comparing each word with a list of common or familiar words or by analyzing each word in terms of number of syllables. Both types of measures, a syllable count and unfamiliar word identification, have been programmed for computer analysis.

If the readability is estimated by using a word list to identify unfamiliar or uncommon words, the list is entered into the computer as is an internal dictionary to identify misspelled words. Then, any word from the text sample that is not in this word list or dictionary is considered unfamiliar for calculating readability estimates. A special routine is often included in the program to handle various forms of the listed words such as plurals, possessives of nouns, and derivatives of verbs.

The syllable count algorithms operate on the principle that the more syllables, the more difficult is the word. The computer can be programmed, through a word dictionary, to determine the number of syllables in a word and use that information in determining a difficulty index.

b. Syntactic complexity. The second major measure used in calculating readability estimates concerns the syntactic or grammatical complexity of the textual information. Although various measures have been used to index syntactic complexity (e.g., number of prepositional phrases, words in main and subordinate clauses, and minimal terminable units), the typical measure is based on the number of words in the sentence, which readily lends itself to computer analysis.

The results of these text analyses can be used either to revise particular aspects of the text to improve its readability or to describe the readability level of the material as it stands. The descriptive use of text analysis is exemplified by publishing companies using computerized typesetting. Computerized readability formulas are included in the computer typesetting system to provide an estimated readability level for each publication so that readers can select materials commensurate with their reading skills. An example of the use of computer-based text analysis to revise instructional materials is a system recently developed for the Navy by Kincaid, Aagard, and O'Hara (1980). This system, called CRES (computer readability editing system), was designed "to improve the

ease of comprehending Navy technical manuals and training materials." In addition to calculating a readability estimate of a given section of text, CRES flags words that are uncommon or misspelled and sentences that are too long, and it also suggests simpler replacements for words that are too difficult.

Research and Evaluation

The use of the computer in collecting and analyzing research data has a history as old as the computer itself. Most of the early research for which the computer was used was basic research in the physical and natural sciences and engineering in university settings. During the 1960s, however, with the advent of programmed instruction, criterion-referenced testing, and mastery learning, educators began to use the computer to evaluate various aspects and instructional procedures. The computer can even collect, store, and analyze the cost and instructional effectiveness data of an entire computer-based instructional system.

Test Item Evaluation. Instructors can collect and analyze a number of different measures of student performance to evaluate each test item. Of course, the particular measures collected and how they are analyzed and interpreted will depend on the purpose for the test. For example, if the test is intended for maximum discrimination among students, test items answered correctly by half of the students will be of more value than those answered correctly by nearly all of the students. In a mastery-based course, on the other hand, test questions anwered incorrectly by 50 percent of the students would be identified as poor questions (those needing revision or indicating poor instruction).

This information can be used by the course developer to revise the test materials. The measures that might be collected in this formative evaluation process include (1) the percentage of students answering each question correctly, (2) the percentage of students selecting each alternative on multiple-choice questions, (3) the nature of errors on constructed response answers, (4) the item/total-score correlation for each item, and (5) mean standard deviations, distributions, and various reliability coefficients for test questions concerned with each objective, lesson, or the total course.

Evaluation of Instructional Materials. The computer can collect and analyze information about instructional materials in much the same way as for test materials, with many of the student performance measures being relevant to both. However, to provide adequate information for the formative evaluation of instructional materials might require additional information such as (1) time for each student to complete each study assignment, (2) student ratings concerning interest and instructional value of various lesson materials, (3) effectiveness of various remediation materials in terms of pre- and posttest changes effected by each remediation activity, and (4) open-ended student comments concerning lesson materials.

Type of Instruction. The computer can also collect and analyze data relevant for evaluating instructional procedures. For example, an instructor may decide to adopt a self-paced procedure for teaching a particular course and to use various student performance and attitude measures to evaluate its success. Here again, many of the same measures may be used to evaluate changes or innovations in instructional procedures as well as to evaluate testing and instructional materials. The advantage of involving the computer in these various evaluation functions is that large amounts of information can be routinely collected, analyzed, and reported.

Aptitude-treatment Interactions. Most attempts to evaluate the quality of instructional materials and procedures fail to consider the possibility that some types of

instruction and material may be more appropriate for some students than for others. Some psychologists and educators argue that no single method or form of instruction can be maximally effective for all students and that instruction should not be designed to fit average students but, rather, to fit groups of students who have particular characteristics or aptitudes. This approach, labelled "adaptive teaching," requires the identification of specific student characteristics that interact best with particular instructional procedures—an area of research known as aptitude-treatment interaction (ATI). ATI research involves measuring the differences in individual characteristics such as intellectual ability, cognitive style, and personality. The degree of association among these "predictor" variables and student performance under different instructional treatments is then determined. On the basis of these findings, different groups of students can subsequently be assigned to different types or modes of instruction or to different versions of the course. Although ATI research has not been widely successful in the field of education and training (see Federico, 1978 for a review), it has generated a substantial amount of interest. The computer has played a central role in this area due to its ability to perform the complex multivariate statistical analyses on which ATI research is based.

Computer-based Communication

Computers can be used in support of education and training to foster communication within a particular course or school, as well as among institutions, by permitting instructors and students to interact with each other via the terminals.

Within-course Communication. The computer can be used to facilitate various types of communication between students and the course instructor. Course notices and announcements can be entered, students can send notes or specific questions to the instructor and receive answers via the computer, and information can be collected from the entire class (e.g., conflicts with a final exam schedule or surveys of student attitudes concerning various aspects of a course). By using the computer as the medium for communication, problems arising from the scheduling of information exchanges between students and instructor can be resolved.

Computer Networks. In computer network, computers are connected to permit users to communicate with each other. These networks can be used to support a variety of education and training functions either within a particular institution or among various institutions.

1. Intra-institution networks. When a number of computers are connected, the network can be used to accumulate and process student records and performance in all courses, to distribute computer-based lesson materials from a central source, and to share equipment such as printers, videodiscs, and film displays.

2. Inter-institution networks. When a network connects computers located in various educational institutions, various institutions specializing in the development of certain instructional materials can share instructional resources and programs.

A major problem that continues to plague CAI at all levels of application is the high cost of developing course materials. Computer networks provide one method of potentially reducing these costs by facilitating software exchange and sharing among institutions with similar instructional objectives.

CONCLUSIONS

Over the years, the computer has assumed a tremendous role in the conduct of education and training. In military and industrial organizations, CMI systems have developed more rapidly than have CAI systems for operational training. However, many of the functions for both CMI and CAI described herein are employed today to provide instruction that is cost effective and instructionally efficient in comparison to conventional instruction.

Increasing familiarity with the range of possible educational computer functions can help those directly responsible for training operations to optimize implementation of computer-based instruction.

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APPENDIX

TAXONOMY OF COMPUTER-BASED
EDUCATION AND TRAINING FUNCTIONS

TAXONOMY OF COMPUTER-BASED
EDUCATION AND TRAINING FUNCTIONS

1.0 Instructional functions

  1.1 Tutorial computer-assisted instruction

    1.1.1 Information presentation
    1.1.2 Drill and practice
    1.1.3 Tutorial function

  1.2 Laboratory computer-assisted instruction

    1.2.1 Simulation

      1.2.1.1 Equipment simulation
      1.2.1.2 Simulation of complex systems and processes

    1.2.2 Complex problem solving and modeling
    1.2.3 Educational games

2.0 Management functions

  2.1 Diagnosis

    2.1.1 Precourse diagnosis
    2.1.2 Within course diagnosis

  2.2 Prescription

    2.2.1 Precourse remediation
    2.2.2 Within course prescription

      2.2.2.1 Assignment to alternative course versions
      2.2.2.2 Assignment to alternative lesson formats
      2.2.2.3 Assignment to alternative remediation activities
      2.2.2.4 Student self-prescription

  2.3 Student testing and feedback

    2.3.1 Individualized test selection

      2.3.1.1 Test form selection
      2.3.1.2 On-line versus off-line assignment

    2.3.2 Scoring of tests taken off-line

      2.3.2.1 Preset criterion
      2.3.2.2 Correction for guessing
      2.3.2.3 Question weighting
      2.3.2.4 Scoring based on objectives
      2.3.2.5 Scoring based on performance tests

    2.3.3 Test feedback to students

      2.3.3.1 Test scores
      2.3.3.2 Item analysis
      2.3.3.3 Next assignment

    2.3.4 On-line testing capabilities

      2.3.4.1 Constructed response answers
      2.3.4.2 Varied presentation orders
      2.2.4.3 Individualized test construction

3.4 Computer-based communication

   3.4.1 Within-course communication
   3.4.2 Computer networks

      3.4.2.1 Intra-institution networks
      3.4.2.2 Inter-institution networks

DISTRIBUTION LIST